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A variety of human factors support services (e.g., function allocation, training system development, cockpit design) are required in the development of naval air weapon systems. For many, perhaps all, such services adequate system Functional Requirements (FRs) are a necessary prerequisite. Current practice for preparation of FRs, useful to human factors engineers, is inadequate. One solution to the problem is a manual of instructions for preparing adequate FRs. This

report presents the consensus of opinion of a group of experienced system developers about what a manual of instructions for writing FRs should contain.

REPORT NO. NADC-78076-60

USE OF GROUP OPINION TO PLAN CONTENT OF AN INSTRUCTION MANUAL FOR WRITING FUNCTIONAL REQUIREMENTS

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SUMMARY

A variety of human factors support services (e.g., function allocation, training system development, cockpit design) are required in the development of naval air weapon systems. For many, perhaps all, such services adequate system Functional Requirements (FRs) are a necessary prerequisite. Current practice for preparation of FRs, useful to human factors engineers, is inadequate. One solution to the problem is a manual of instructions for preparing adequate FRs. This report presents the consensus of opinion of a group of experienced system developers about what a manual of instructions for writing FRs should contain.

CONCLUSIONS

The opinions of experienced Human Factors Engineers (HFEs) confirm justifications provided in Subtask A.1 of Program Element No. 62763N for preparation of an instruction manual for writing Functional Requirements (FRs). Briefly, FRs are useful prerequisites for most human factors support services in system development. For function allocation, design of equipment used by humans and human role definition, FRs are mandatory prerequisites. To be useful to HFEs, system FRs must be written to permit more than one means of accomplishing the required functions ("implementation free" FRs). Experienced HFEs agree a document of instructions for writing FRs could and should be prepared. The document must: 1.) define "implementation free" FRs, 2.) provide numerous, specific examples of adequate and inadequate FRs, 3.) present and suggest solutions for commonly-encountered problems in preparation of FRs and 4.) present clear steps to follow in preparing FRs.

Human Factors Engineers agree that writing FRs requires a cooperative effort between all disciplines involved in system development. Daily, active, work interaction, between HFEs and non-HFEs (traditional engineering personnel), was an agreed-upon crucial source of information for writing system FRs. However, opinions of HFEs revealed a potentially serious problem with the effectiveness of the interaction. Human Factors Engineers tend to misjudge opinions held by non-HFEs about HFEs and human factors support services in system design. Contrary to the HFEs' predictions, opinions of non-HFEs show an understanding of and need for, involvement of HFEs and the utility of human factors support in system design. If FRs are mandatory for at least some necessary human factors support services, if adequate FRs depend on effective interaction between HFEs and nHFEs, and if opinions of HFEs about nHFEs reported here persist, even a well written instruction manual may not be sufficient to insure preparation of FRs useful to HFEs. Before an instruction manual can be useful, HFEs must carefully examine opinions they hold about, and attribute to, nHFEs.

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INTRODUCTION

This document was prepared under Program Element No. 62763N, Task Area No. WF55-525-000, Subtask A.1 - Tasks and Functions to be Allocated to Humans: Develop Functional Requirements Methods. A Program Management Summary (PMS), supporting the Subtask, provides supplementary details for the task objective. Briefly, the objective of the task is to: "Prepare a manual or handbook for use by Human Factors or non-Human Factors engineers which: 1) communicates the need for the development and use of FRs (Functional Requirements) in the design process; and 2) describes the procedures and methods to be used for the generation of FRs." Additionally, the PMS states;

1.) all system design efforts require adequate "implementation free" FRs,

2.) inadequate FRs decrease effectiveness of human factors engineering and may lead to expensive and unnecessary system design,

3.) criteria for distinguishing between good and bad FRs are needed and

4.) advice and counsel from experienced system developers should guide the effort.

To prepare a preliminary outline for the proposed manual, interviews with senior members of the Naval Air Development Center (NADC) Human Factors Division (HFD) were conducted. The interviews revealed often conflicting and sometimes vague guidance. Opinions from a larger, more diverse group and an orderly procedure for obtaining and systematizing the opinion were needed. The Delphi method (Quade & Boucher, 1968) is tailor made to fill the need.

The Delphi method, first developed for the military by the RAND Corp. (Dodge & Clark, 1977) is described in detail elsewhere (Linstone & Turroff, 1975). Briefly, the Delphi method employs a series of questionnaires. The first questionnaire, usually requiring essay responses to a few general questions, is intended to gather as much information as possible about a topic. The monitor summarizes the first returns and re-distributes the results as a second questionnaire. Usually the second and subsequent questionnaires are in multiple-choice format. The third and subsequent questionnaires include feedback to respondents by showing each respondent his responses in comparison to the group's responses. Respondents are permitted to change their opinions and are encouraged to explain any atypical opinions. The explanations may also be included as feedback for consideration by all respondents. The process continues until the monitor concludes he has as much consensus of opinion as he can get. The process is conducted with assurance of anonymity of opinion. Consequently, each respondent considers all opinions free of any effect from association between individuals and opinions.

"Delphi may be characterized as a method of structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem." (Linstone & Turroff, 1975; pg. 3). In this case, the complex problem is to determine the content of an instruction manual for writing FRs. The appropriate individuals to provide advice and counsel are HFEs experienced in providing support services to naval weapon system development. The Delphi method provides an orderly and systematic procedure for determining consensus of opinion from the group about the problem. The opinions obtained from experienced HFEs and presented in this report are intended as guidance to writers of an instruction manual for writing FRs that will be useful to HFEs.

METHOD

Respondents. Sixteen professional members of the NADC Human Factors Division (HFD) and 33 members of the NADC Systems Department (SD) answered questionnaires. HFD respondents included three Navy Medical Service Corps Officers and 13 civilians. Eleven civilian HFD respondents were Engineering Psychologists, one was an Electrical Engineer and one a General Engineer. SD respondents included 23 Electrical Engineers, eight General Engineers, one Aerospace Engineer and one Mechanical Engineer.

SD respondents claimed some work interaction with human factors engineers. All respondents had at least one year's experience in system development work. Lastly, all respondents volunteered their involvement and their responses remained anonymous throughout the effort.

Procedure. A sequence of three questionnaires was provided to the HFD respondents. Questionnaire One asked 10 general questions about FRs and was intended to stimulate wide-ranging essay responses. A copy of Questionnaire One is provided in Appendix A.

Responses to Questionnaire One were summarized, re-written as 210 single sentences clustered into 11 general issues and resubmitted to HFD respondents as Questionnaire Two. The 11 general issues were presented in 11 different tables, one issue to a table, in Questionnaire Two. Each table included a heading and a number of associated items. Respondents were instructed to combine the heading, successively, with each item in the table to form sentences. For each resulting sentence respondents were asked to select one of five versions of agreement, viz., 1) agree completely, 2) tend to agree, 3) uncertain if agree or disagree, 4) tend to disagree and 5) disagree completely. For example, the heading for Table 1 in Questionnaire Two was: "Functional Requirements are:". One item in Table 1 was: "exclusively a human factors construct." Respondents then formed the sentence "Functional Requirements are exclusively a human factors construct" and selected one of the five versions of agreement. Or, respondents could ignore any item by not indicating a response. A copy of Questionnaire Two is shown in Appendix B.

Questionnaire Three was identical to Questionnaire Two except response distributions, obtained from results in Questionnaire Two, were shown for each item along with the respondent's responses in Questionnaire Two. Thus, for each item, respondents could compare their responses with the responses of the entire group. Questionnaire Three provided respondents an opportunity to change responses.

One of the 11 issues in Questionnaire Two concerned estimates, by human factors engineers (HFEs), of beliefs held by non-human factors engineers (nHFEs) about HFEs and human factors support services in system development (See Table B10, Appendix B). To determine opinions actually held by nHFEs, 33 nHFEs from the SD provided their opinions on a single questionnaire (hence not a Delphi procedure). The questionnaire used with SD respondents was a duplicate of one table of Questionnaire Two used with the HFEs (See Table B10, Appendix B) with an appropriate change to the table heading. Thus, for the issue concerned with

beliefs held by nHFEs, two groups responded to the items. One group, the HFEs, speculated about beliefs held by nHFEs. The other group, the nHFEs, stated their beliefs for comparison to speculations provided by the HFEs.

RESULTS

Response distributions in Questionnaire Three for HFEs and response distributions in the single questionnaire for nHFEs represent group opinion for each item. Group opinion represented: 1.) consensus of opinion for agreement, 2.) consensus of opinion for disagreement or 3.) no consensus of opinion or uncertainty. Response distributions representing consensus of opinion differed in degree of agreement from complete agreement to complete disagreement. To select distributions representing consensus of opinion, observed distributions were compared to distributions expected by chance. Any observed distribution with a probability of occurrence, by chance, of 0.140 or less was accepted as representing consensus of opinion for the corresponding questionnaire item. For each distribution accepted as representing consensus of opinion the median was computed. In data reported here the median value will fall on a scale between 1.00 and 5.00. A median of 1.00 represents complete agreement while a median of 5.00 represents complete disagreement. A detailed discussion of the analysis procedure is provided in Appendix C. Response distributions for every item in the questionnaires are provided in Appendix B. Results of the analyses are presented in Tables 1 through 4.

Human factors engineers were allowed to change responses given in Questionnaire Two on Questionnaire Three. For any response change, three alternative outcomes are possible: a.) change between categories with equal frequencies, b.) change from a category with a lower to a category with a higher frequency or c.) change from a category with a higher to a category with a lower frequency. The case wherein a respondent did not respond to an item may be treated as if it were a sixth category. Consider the following example of a Questionnaire Two distribution:

C_1	C_2	C_3	C_4	C_5	C_6
6	3	3	2	1	1

C_1 represents the category--I AGREE COMPLETELY, C_2 represents--I TEND TO AGREE and so on. C_6 represents the case where a respondent did not respond to the item. Assume a respondent had selected a response to C_3 in Questionnaire Two. If the respondent elects to change his response on Questionnaire Three, the change must be to C_1, C_2, C_4, C_5 or C_6. If he changes his response to C_1, the change would be classified as a change "From Lower to Higher" (f=3 to f=6). If he changes to C_2, the change would be classified as a change "From Same to Same" (f=3 to f=3). If he changes to C_4, C_5 or C_6, the change would be classified as a change "From Higher to Lower" (f=3 to f=2, f=1 or f=1). Table 5 presents the results of the classification procedure.

Response distributions for each item represent group opinion about the item. One statistical summary of the group's opinion is the distribution median (the point on a scale on each side of which there are 50% of the cases in the distribution). In Table 10 of Questionnaire Three, HFEs provided their estimate of opinions held by nHFEs about HFEs and their role in system development. The

identical items of Table 10 (Questionnaire Three) were provided to NHFEs to obtain their opinions about HFEs and the role of HFEs in system development. Table 6 shows items for which a statistically significant (two-tailed) difference between medians was observed by application of the Medians Test (Siegel, 1956) to each pair of distributions. In Table 6 items are presented in order from the largest to the smallest difference between distribution medians.

Table 1

Human Factors Engineers Agree

FRs are:

Item	Median
useful if they facilitate the work for which they are needed.	1.17
mandatory in system development since they and they alone are fair standards by which the adequacy of the system can be evaluated.	1.23
mandatory for development of any system when at least one human is to be a component of the system.	1.23
useless if they do not facilitate the work for which they are needed.	1.23
statements of WHAT a system must accomplish.	1.23
"activities a system must perform independent of the means of accomplishing the activities."	1.30
"what a thing (system, display, control) is to accomplish."	1.30
"mandatory attributes that a system must possess to accomplish its defined mission."	1.39
written to a level of detail determined by the use to which the functional requirements will be put.	1.50
presented in hierarchical form starting with general and working to specific requirements.	1.75
seldom, if ever, adequately prepared.	1.75
the end product of a procedure or process.	1.81
always a means to an end.	1.83
never written once in the development of a system; rather they are written at the start and continuously refined as more information becomes available.	1.95
related to the concept of "degrees of freedom" in that as equipment is ever more precisely defined, the corresponding loss in alternative approaches to accomplish system functions is similar to a reduction in "degrees of freedom."	1.95

Table 1 (Continued)

Item	Median
FRs should be written by:	
a group of writers that represent all the different interests in the system development process.	1.93
someone who understands thoroughly the warfare area (e.g., ASW, air-to-air combat) for which the system is being developed.	1.96
Likely sources of information for writing FRs include:	
Operational Requirements.	1.39
Specific Operational Requirements.	1.50
interviews with non-human factors engineers directly involved in the system development process.	1.92
statements of Navy needs.	1.94
experience gained by direct, daily involvement of the writer(s) with non-HF engineers on the development team.	2.05
Adequate FRs are needed for:	
function allocation procedures.	1.08
panel design.	1.13
control design.	1.13
display design.	1.13
operator role definition.	1.13
crew station design.	1.18
maintainer role definition.	1.25
crew size determinations.	1.25
functional flow block diagramming.	1.33
task analyses.	1.33
system test and evaluation.	1.33
operational sequence diagramming.	1.56

Table 1 (Continued)

Item	Median
Adequate FRs are needed for:	
selection of equipment components.	1.56
construction of time line analyses.	1.75
FRs should be written without reference to:	
outcomes of an implied function allocation process. Thus, "Accomplish MK 46 torpedo launch" is a better FR than "Pilot accomplish MK 46 torpedo launch."	1.83
specific human responses. Thus, "Pilot launch MK 46 torpedo" is a better FR than "Pilot press LAUNCH button on a torpedo control panel."	1.83
The probability adequate FRs can be written depends, in part, on:	
point in the development process when FRs are written--the earlier in the process, the higher the probability adequate FRs can be written.	1.63
A document of instructions for writing FRs:	
if well written and understandable to individuals in system development, would be useful.	1.50
could be written.	1.86
A document of instructions for writing FRs should include a section:	
clearly defining functional requirements and the general issues involved in writing good ones.	1.17
of a generous number of examples of adequate, marginal and inadequate FRs along with explanations why each of the examples was classified as it was.	1.30
describing the kinds of problems typically encountered in writing functional requirements along with suggestions for overcoming the problems.	1.39

Table 1 (Continued)

A document of instructions for writing FRs should include a section:	
Item	Median
providing an example of how an existing system evolved and where in the evolution functional requirements would have been needed, what the functional requirements should have looked like and how they would have been used by human factors engineers.	1.50
describing the various uses HF engineers have for functional requirements.	1.90
on the need for clarity in thinking and writing along with suggestions and references for achieving clarity.	1.94
nHFEs believe HFEs:	
should not have final authority in any decision in the development process.	1.83
provide services that cost too much money to be worthwhile in the development process.	1.88
do not appreciate the speed with which things happen during the system development process.	1.95
can't respond to system development problems without first proposing a lengthy "investigation."	2.00
should be involved in the system development process but only after major equipment components have been selected.	2.00
HFEs believe nHFEs:	
are biased to think in terms of equipment solutions to system functions.	1.50
do not appreciate the complexity, time and effort involved in human factors support services.	1.72
are quick to cut funds for human factors support services from the budget when funding is cut.	1.72
assume humans will adapt to the demands of the man-machine interface since humans have always done so in the past.	1.83
assume training will take care of helping humans adapt to any demands the system might impose.	1.83

Table 1 (Continued)

HFEs believe nHFEs:

Item	Median
will abandon even an excellent HF engineering suggestion if the suggestion interferes with a constraint imposed by the needs of the equipment.	1.88
are unconvinced about the usefulness of an HF discipline.	1.93
are willing to give only "lip service" to the need for HF involvement in the system development process.	1.93
assign as many functions as possible to equipment and assign to humans only what unavoidably remains.	1.94
do not know how and why HF engineers do what they do.	2.00
do not feel any responsibility for the adequacy of human performance in the developed system when it is delivered to the fleet.	2.00
are afraid HF engineers will interfere with the non-HF engineer's prerogative to make system design decisions.	2.08
are convinced the HF discipline has some, but a vague, role in the system development process.	2.12
want to develop new systems by improving the old ones.	2.12

Table 2

Human Factors Engineers Disagree

Item	Median
FRs are:	
statements of WHEN a system must accomplish something.	4.20
useful only in some subsequent human factors support service.	4.61
exclusively a human factors construct.	4.88
FRs should be written by:	
almost anyone who wants to write functional requirements since the process is relatively simple once you know what is required and considered adequate.	4.25
Likely sources of information for writing FRs include:	
outcomes of a function allocation procedure.	4.14
FRs should be written without reference to:	
equipment. Thus "destroy enemy forces" is a better FR than "Destroy enemy submarines."	4.50
A document of instructions for writing FRs:	
is not worth the effort required to produce it.	4.06
is impossible to write since the procedure varies too much from one system to another.	4.13
is not needed since the procedure for writing functional requirements is an art similar to writing musical masterpieces and thus cannot be described.	4.17
is not needed since the procedure for writing functional requirements is well known.	4.25

Table 2 (Continued)

HFEs believe nHFEs:

Item	Median
should be reduced to a very low level in the decision-making process in system development.	4.00

Table 3

Non-Human Factors Engineers Agree

HFEs:

Item	Median
have a useful role in the system development process.	1.42

Table 4

Non-Human Factors Engineers Disagree

HFEs:

Item	Median
try to "horn in" on a process where they are not wanted.	4.02
don't provide anything more than common-sense suggestions to the system development process.	4.13
provide services that cost too much money to be worthwhile in the development process.	4.25
should be involved in the system development process but only after major equipment components have been selected.	4.26
are arrogant.	4.38
are useful only in support services (e.g., training system design, test and evaluation) after prototype models of the system have been built.	4.47
should be restricted to designing comfortable and attractive crew stations.	4.58
have little or nothing of value to contribute to the system development process.	4.75

Table 5

Response Changes

Respondent Code Number	Change From: Lower to Higher Frequency	Change From: Higher to Lower Frequency	Change From: Same to Same Frequency
6	0	0	0
16	21	2	2
19	26	1	2
24	6	0	0
28	15	3	2
30	10	5	0
32	5	0	2
37	9	7	0
39	15	2	1
41	4	0	0
53	12	6	3
66	20	0	0
69	4	0	0
81	7	1	0
84	7	1	0
91	3	2	0

Table 6

Differences of Opinion Between Human Factors Engineers (HFEs) and non-Human Factors Engineers (nHFEs)

(Medians of nHFEs' data predicted by HFEs (arrow down) vs. Medians of data provided by nHFEs (arrow up))

Items		Agree 0.5 — 3.0 — Disagree 5.5
Human Factors Engineers:		
provide services that cost too much money to be worthwhile in the development process.	**	HFEs / nHFEs
should be involved in the system development process but only after major equipment components have been selected.	**	
are useful only in support services (e.g., training system design, test and evaluation) after prototype models of the system have been built.	**	
provide services that are too time consuming to be worthwhile in the development process.	**	
have a useful role in the system development process.	**	
don't provide anything more than common-sense suggestions to the system development process.	**	
should be restricted to designing comfortable and attractive crew stations.	**	
are useful only to suggest arrangements for the location of controls and displays at the man-machine interface.	**	
have little or nothing of value to contribute to the system development process.	**	
overemphasize the role of the human in the system.	**	
may be O.K., but the ones engineers have actually worked with did not live up to expectations.	**	

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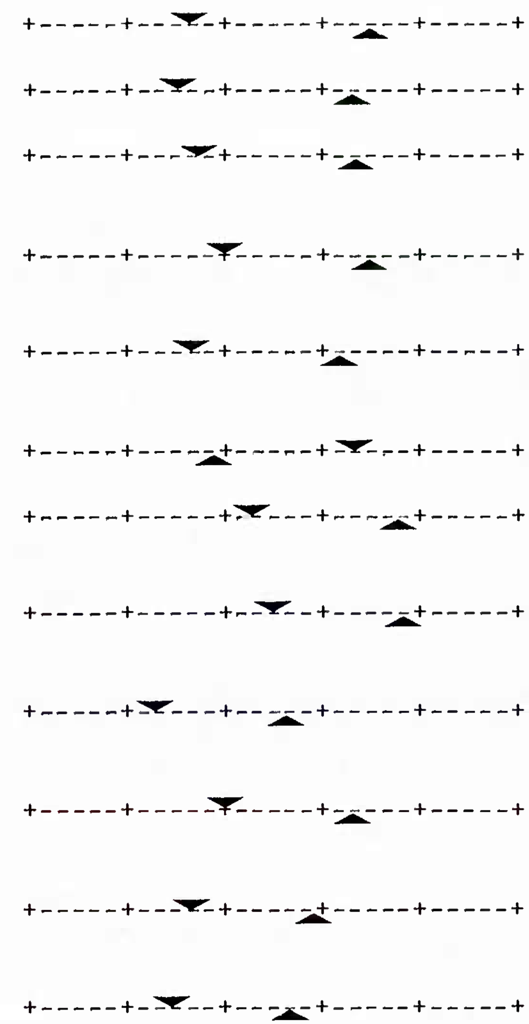
Table 6 (Continued)

Items		Agree 0.5 — 3.0 — Disagree 5.5
Human Factors Engineers:		
try to "horn in" on a process where they are not wanted.	**	
promise a great deal but deliver very little.	**	
should not have responsibility for deciding if a human or a machine should accomplish a given system function.	**	
are unwilling to "work in the trenches" with working level non-human factors engineers.	**	
treat each system problem they are asked to help resolve as if it were the first time the problem had ever come up.	**	
are welcomed in the system development process.	**	
use a lot of jargon that even other human factors engineers do not really understand.	**	
are responsible for any inadequacies in communication or cooperation between non-human factors and human factors engineers.	**	
should not have final authority in any decision in the development process.	**	
are unaware of the factors that really determine events and decisions in the system development process.	*	
are insensitive to demands and responsibilities non-human factors engineers face in system development.	*	
can't respond to system development problems without first proposing a lengthy "investigation."	*	



** indicates $p \leq 0.01$
* indicates $p \leq 0.05$

DISCUSSION

Discussion about the procedure. The procedure used in this exercise with HFEs was a variation of the traditional Delphi procedure. The amount, type and form of feedback provided differed from that used in most applications of the Delphi procedure (See Linstone & Turroff, 1975 for examples). HFEs were provided feedback once between a second and third (here also last) questionnaire. HFEs were asked, in the third questionnaire, to compare their responses to responses of the group. Respondents could change their responses after noting how the group had responded. Explanations of atypical opinions were not requested; nor, if volunteered, used. The procedure here was a compromise between a major advantage of the Delphi procedure, viz., ultimate arrival at maximum consensus of opinion of the group, and a major disadvantage, viz., the time and effort required from respondents.

In Questionnaire Three, respondents indicated response changes from responses in Questionnaire Two. Fifteen of 16 HFE respondents made changes (See Table 5). Table 5 shows a majority (162 of 206) of the changes were from a category with a lower response frequency to a category with a higher response frequency. If feedback provided in this exercise prompted changes of opinion, results in Table 5 show opinion was steered toward greater consensus. For nHFE respondents, only a single questionnaire, hence not a Delphi procedure, was used.

Discussion about what Functional Requirements (FRs) are. The following discussion is intended to structure results shown in Tables 1 and 2 under the heading FRs are.

Discussion is restricted to FRs for Naval air weapon systems. A Naval air weapon system may be defined as a collection of interdependent components serving a common purpose of attack or defense in a potential or actual fight predominantly involving Navy people and airborne equipment. Such systems exist on a continuum extending from conception to retirement from service use. For convenience in subsequent argument, the continuum may be divided into two parts. The earlier part can be called the pre-deployment phase and includes the traditional: a.) Program Initiation, b.) Full Scale Development, and c.) Production Phases common in Weapon System Development. The later part may be called the deployment phase. The deployment phase begins with fleet introduction and ends with retirement from service use.

For a system well into the deployment phase, it would be possible to construct a hierarchical list of all (man and machine) components. Hierarchical listing begins with major components. Major components are sub-divided into sub-components, sub-components into their sub-components and so on. The resulting list illustrates what can be called structural interdependence since removal of any component from the list removes all of that component's sub-components. For example, if the component--Pilot--is removed, all the Pilot's sub-components (e.g., visual system) are also removed. The Pilot and his visual system are structurally interdependent.

The proposed list could be written to almost any degree of explicitness. The degree of explicitness selected depends on who will use the list for what purpose. Thus, one degree of explicitness is appropriate if one is to describe the system to attendees at a Rotary Club luncheon and another degree of explicitness if one is responsible for ordering all necessary replacement components for the system during its use.

The degree of explicitness selected depends on availability of information about a component. For example, one could list: Operator or Pilot or Helo Pilot or H-2F Pilot and so on to LCDR. John Smith. Clearly, one could not list John unless one knew John would be a component of the system. Hence, availability of information sets limits on the degree of explicitness one may select. Note however, because information is available does not mean it must be used. The choice between listing--Pilot--and--LCDR. John Smith-- depends, as before, on who is making the list for what purpose. In any case, the main point is the proposition that maximum degree of explicitness is possible for a system well into the deployment phase because maximum amount of information about the system is available.

For each item in the list it must be possible to list an associated function or functions. Since, if for any component no function can be specified, the component does not rightfully belong in the list. Awful problems are encountered in listing functions. Some components have many functions. Identical components may have different functions while different components may have identical functions. And, the problems are especially acute in listing diverse functions of human components. It is not suggested here that listing functions is quick, easy, cheap or fun. It is argued only that it must be possible to list them. The difficulty of the task is irrelevant to the argument.

If functions are associated with each component in a hierarchical list of components, the functions are also interdependent. This interdependence may be called functional interdependence. Thus, for example, failure of a lock washer under a machine screw in the power amplifier of a Radar Receiver and so on up the hierarchy, should result in failure (ignoring the concept of degraded modes of operation) of one or more system functions. Seldom is functional interdependence so tightly knit that failure of a component, at the very bottom of a list written to a very high degree of explicitness, inevitably results in system failure. But, accident analyses sometimes uncover surprising examples of tight functional interdependence. In any case, the function of our example lock washer and the functions of the system are interdependent.

A statement of functions for any component of a system is incomplete unless all conditions that can influence successful accomplishment of the functions are identified. As with functions, style, format and degree of explicitness for itemizing conditions are optional and probably reflect their intended use. But, <u>all</u> conditions must be identified in whatever scheme is used. Consequences of ignoring any condition are directly related to frequency of occurrence of the condition and criticality of the function during system use. Incidentally, a distinction between function and condition depends on the cataloging scheme used. For example, a function may be--land aircraft on Carrier flightdeck. Alternatively, the function may be--land aircraft--and associated conditions may include--on a Carrier flightdeck. This illustration of variation in cataloging

schemes should not, however, obscure the important issue, viz., statements of functions are incomplete unless all conditions affecting successful accomplishments of the function are identified.

To this point, argument has attempted to convince the reader that a hierarchical list of all components of a system well into the deployment phase could be written. For each component listed, one or more functions could be identified. For each function all conditions potentially affecting accomplishment of the function must accompany the function.

Consider next determinants of conditions affecting functions. At least two sources may be identified. One source is "higher authority," the other is from the components themselves. Navy management sets various conditions on system functions chiefly based on time, money and anticipated threat considerations. Since concern here is with an existing system, it is reasonable to assume a set of necessary conditions provided by "higher authority" must have been available at one time in the development of the system. In this argument, conditions and functions assigned by "higher authority" are not issues for debate, they are given. Then too, conditions imposed by components are far more important to this discussion. Such conditions are imposed by capabilities of the component itself. For example, for the component--Pilot--one function may be--land aircraft. Conditions associated with the function may include: a.) at night, b.) on a Carrier flightdeck, c.) in a state seven sea and so on. Now, if one assumes the component--Pilot--can accomplish the function under specified conditions, the component, function and conditions are in accord. If however, the component--Pilot--were instead--ENS. Jack Smith--it is possible Jack could land the aircraft on a Carrier flightdeck at night, but only in a flat sea. We must either replace Jack or alter the condition--in a state seven sea. The direction we go will depend on whether we permit components to determine functions or functions to determine components. The important point for this discussion is that components set unique conditions (hereafter called constraints) on functions and are separable from conditions imposed by other sources.

When applied to a system well into the deployment phase, the process described above could produce a hierarchical list of all components, associated functions and for each function an associated list of conditions and associated constraints.

Now, if one discards the list of components and the associated constraints, what are left are "implementation free" functional requirements for the system under consideration.

The foregoing operational definition of "implementation free" FRs reflects one interpretation of the results shown in Tables 1 and 2 under the heading <u>FRs are</u>. To identify and discuss implications of the definition is not the purpose of this report. Rather, the purpose is to provide one possible definition, based on an interpretation of opinions of experienced HFEs. Writers of the manual or guidebook may accept, modify or reject the definition above; they cannot however, escape the need for including some precise definition of "implemenation free" FRs in the final document.

Discussion about who should write FRs. Consensus of opinion among HFEs is that FRs should be written by a group of writers that represent all the different interests in the system development process (See Table 1). This finding is opposed to a suggestion in the Program Management Summary that nHFEs be responsible for writing FRs adequate for use by HFEs. Furthermore, HFEs agree writers of FRs must understand thoroughly the warfare area (e.g., ASW) for which the system is being developed (See Table 1). Lastly, HFEs disagree that the process of writing FRs is relatively simple and can be followed by the inexperienced (See Table 2).

Discussion about likely sources of information for writing FRs. Table 1 shows written and verbal sources of information. The written sources cited (e.g., Operational Requirements) are documents characteristic of the earliest phases in system development. Verbal sources include interviews with nHFEs and the communication involved in direct, daily involvement with nHFEs in their working environment. Taken together, the results suggest adequate FRs can not be written by HFEs simply from documents routinely provided during system development; rather, FRs should be written by a team of individuals, representing various skills, in active daily contact during, especially, the early part of the system development process.

Discussion about human factors support services for which adequate FRs are needed. In Table 5 of Questionnaire Two (See Appendix B), 19 human factors support services are listed. Table 1 shows HFEs agree that adequate FRs are required for 14 of the 19. Table 1 further shows HFEs agree completely (Mdn. $\leq$ 1.49) that adequate FRs are required for 11 of the 14. The results support the notion that adequate FRs are a necessary prerequisite for almost all human factors support services to weapon system development.

Discussion about a document of instructions for writing FRs. Results in Tables 1 and 2 under the heading: _A document of instructions for writing FRs_: may be summarized as follows. The document is: 1.) needed, 2.) possible, 3.) worth the effort required to produce it and 4.) if well written, would be useful. The results provide support, from experienced HFEs, for the established Work Unit.

Discussion about content of the document. Table 1 shows HFEs agree a useful document should include: 1.) a clear definition of FRs, 2.) a discussion of the issues involved in writing good FRs and 3.) a description of the problems commonly encountered in writing FRs and suggested solutions for resolving the problems. Table 1 further shows HFEs recommend the document provide sufficient specific examples to illustrate the differences between adequate and inadequate FRs.

Discussion about opinions held by one group about the other. Results in Tables 1, 2, 3, and 4, under the headings _nHFEs believe HFEs_, _HFEs believe nHFEs_ and _HFEs_ represent consensus of opinion for predictions by or actual opinions of, one group about the other. Taken together, the results show: 1.) HFEs predict nHFEs hold HFEs and human factors support services in low esteem, 2.) HFEs hold nHFEs and the roles of nHFEs in low esteem and 3.) nHFEs do not hold HFEs and human factors support services in low esteem. For items taken to represent consensus of opinion (Tables 1 through 4), HFEs' predictions of nHFEs' opinions are

consistently inaccurate.

The extent of differences of opinion between HFEs and nHFEs may be highlighted by comparison of all items considered by both groups regardless of whether or not consensus of opinion was observed. Table 6 presents 23 of 34 items, considered by both groups, for which a statistically significant ($p \leq .05$) difference between distribution medians was observed. The result in Table 6 provides support for the conclusion that HFEs generally predict that nHFEs hold HFEs and human factors support services in low esteem <u>and</u> that the HFEs are generally wrong. Various explanations for the differences in opinion are possible. However, assuming the beliefs expressed in Table 6 are genuine, a single conclusion appears self-evident. To produce, by cooperative effort among HFEs and nHFEs, system FRs adequate for use by HFEs, the HFEs must first alter their inaccurate beliefs.

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Appendix A

QUESTIONNAIRE ONE

Please provide your responses on sheets of paper and on each sheet print your name and identify your response with the appropriate item number.

Item

1. Try to provide a useful definition of functional requirements. If you cannot, please tell me why you cannot.

2. Have you provided any human factors support to one or more of the following systems: LAMPS, VPX, F-18, VSTOL, PROTEUS, CVTSC, P3C Update, KCX? If yes, which system(s) and what kind of support did you provide?

3. Have you encountered difficulty with inadequate functional requirements in your human factors work? If yes, please describe the difficulties and the circumstances.

4. Do you think you could distinguish between adequate and inadequate functional requirements? If yes, what criteria would you use to make the distinction?

5. Construct any useful example and describe the process you would follow to develop adequate functional requirements. If possible, using your example, provide the functional requirements resulting from the process.

6. Development of functional requirements probably involves communication and cooperation among managers, non-human factors engineers and human factors engineers. Assume poor communication and lack of cooperation among the mix of talent interferes with development of adequate functional requirements. Please describe the most likely kinds of communication/cooperation problems and who would be involved. Then, provide any suggestions to relieve the problems you suspect.

7. Assume you were asked to write a manual or handbook for use by someone to write adequate functional requirements. Do you think such a document could be written? If no, why not? If yes, would anyone in the system design process be able to use the document to produce adequate functional requirements? If no, who would be ruled out? Should non-human factors engineers write the functional requirements? If no, who should? For the last two questions, please state the reason for your choice. Lastly, do you know if such a document exists? If yes, where could I find it?

8. When in the system development process (from concept formulation to retirement of the system from the fleet) are the functional requirements needed? What human factors support service would require them?

9. What information would you need before you could produce adequate functional requirements? If it isn't obvious, where would you get the information?

QUESTIONNAIRE ONE (Continued)

Item

10. Here please provide any comments or suggestions you consider useful to me to help understand functional requirements and their problems.

Appendix B

Table B1

Functional requirements are:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. a list of sentences.	4	8	1	1	2
2. one or more expository paragraphs	5	5	0	3	3
3. presented in hierarchical form starting with general and working to specific requirements.	6	8	2	0	0
4. exclusively a human factors construct.	0	0	1	2	13
5. the end product of a procedure or process.	5	8	2	0	0
6. equal in number to the number of system functions.	1	1	3	5	6
7. seldom, if ever, adequately prepared.	6	8	2	0	0
8. easy to write once you know precisely what is required.	2	6	3	4	1
9. easy to write for a system currently in fleet use.	2	6	2	4	2

- CONTINUE WITH TABLE B1 -

Table B1 (Continued)

Functional requirements are:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
10. defined by the operations one conducts to produce them.	2	1	6	5	2
11. definable only by examples.	0	0	5	6	5
12. statements of goals, objectives or purposes of a system.	4	8	2	1	1
13. difficult to define so that anyone with a typical high school education and access to a dictionary can understand the definition.	1	5	3	4	3
14. mandatory in system development since they and they alone are fair standards by which the adequacy of the system can be evaluated.	11	4	1	0	0
15. mandatory for development of any system when at least one human is to be a component of the system.	11	4	1	0	0
16. of no value after a system has been delivered to the fleet.	0	2	2	3	9
17. neither good nor bad; rather, functional requirements are either useful or useless.	3	4	6	2	1
18. useful if they facilitate the work for which they are needed.	12	4	0	0	0

- CONTINUE WITH TABLE B1 -

Table B1 (Continued)

Functional requirements are:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
19. useless if they do not facilitate or they hinder the work for which they are needed.	11	3	0	2	0
20. different for different uses.	2	7	3	2	2
21. always a means to an end.	5	9	2	0	0
22. always the same for a given system.	3	1	0	7	5
23. never written once in the development of a system; rather they are written at the start and continuously refined as more information becomes available.	3	11	0	2	0
24. "activities a system must perform independent of the means of accomplishing the activities."	10	6	0	0	0
25. "mandatory attributes that a system must possess to accomplish its defined mission."	9	4	2	1	0
26. "what a thing (system, display, control) is to accomplish."	10	4	2	0	0
27. mandatory for at least one of the human factors support services in system development.	11	1	4	0	0

- CONTINUE WITH TABLE B1 -

Table B1 (Continued)

Functional requirements are:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
28. statements of WHAT a system must accomplish.	11	5	0	0	0
29. statements of WHEN a system must accomplish something.	4	4	1	4	3
30. statements of WHO should accomplish system functions.	0	1	0	10	5
31. statements of WHERE (the environment) the functions must be accomplished.	6	5	2	3	0
32. statements of WHY the functions must be accomplished.	3	2	5	2	4
33. written to a level of detail determined by the use to which the functional requirements will be put.	8	8	0	0	0
34. not complete unless all constraints that influence each function are described.	1	10	2	2	1
35. useful only in some subsequent human factors support service.	0	0	1	6	9
36. not complete unless all potential inputs to and expected output of each function are described.	1	9	4	1	1

- CONTINUE WITH TABLE B1 -

Table B1 (Continued)

Functional requirements are:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
37. like the responses in a parlor game where participants try to describe, for example, all the things a Xerox machine can do without giving away that they have a Xerox machine in mind.	2	5	6	1	2
38. related to the concept of "degrees of freedom" in that as equipment is ever more precisely defined, the corresponding loss in alternative approaches to accomplish system functions is similar to a reduction in "degrees of freedom."	3	11	0	1	1

- END OF TABLE B1 -

Table B2

Functional requirements should be written by:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. non-HF engineers for use by HF engineers.	1	2	4	6	2
2. HF engineers for use by HF engineers.	0	0	4	8	3
3. HF engineers for use by non-HF engineers.	0	1	4	7	3
4. someone with a background in both engineering and psychology.	2	8	3	2	0
5. someone with at least one year's experience in the systems development process.	3	9	0	2	1
6. someone who understands thoroughly the warfare area (e.g., ASW, air-to-air combat) for which the system is being developed.	2	12	1	0	0
7. anyone who understands what is needed and has the skill, interest and ability to think and write clearly.	3	9	2	0	2
8. anyone who has written adequate functional requirements at least once.	1	7	2	6	0
9. anyone working under supervision of an experienced functional requirements writer.	1	6	3	4	2

- CONTINUE WITH TABLE B2 -

Table B2 (Continued)

Functional requirements should be written by:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
10. almost anyone who wants to write functional requirements since the process is relatively simple once you know what is required and considered adequate.	0	1	1	8	6
11. individuals who will use the functional requirements.	0	2	10	4	0
12. system development management personnel.	0	5	4	5	2
13. active duty fleet personnel who represent people who will ultimately use the system.	0	2	3	9	2
14. a group of writers that represent all the different interests in the system development process.	2	14	0	0	0

\- END OF TABLE B2 -

Table B3

Functional requirements are the same or nearly the same as:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. Operational Requirements.	0	1	5	4	5
2. Specific Operational Requirements.	0	4	4	4	4
3. Development Concept Papers.	0	0	1	11	4
4. Proposed Technical Approaches.	0	1	2	7	5
5. Mission Element Need Statements.	0	5	7	2	1
6. Specific Behavioral Objectives.	0	6	1	6	3
7. entries in a task analysis.	0	2	4	5	4
8. entries in a functional flow block diagram.	1	6	2	4	2
9. entries in an operational sequence diagram.	1	3	3	6	2

- CONTINUE WITH TABLE B3 -

Table B3 (Continued)

Functional requirements are the same or nearly the same as:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
10. outcomes of a function allocation procedure.	0	4	1	5	5
11. outcomes of a methods and media analysis.	0	2	4	3	6
12. operator/maintainer roles.	0	1	3	8	3
13. operator/maintainer duties.	0	1	3	8	3
14. operator/maintainer tasks.	0	4	1	5	5
15. statements of Navy needs.	0	2	3	9	2

- END OF TABLE B3 -

Table B4

Likely sources of information needed to write functional requirements include:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. Operational Requirements.	9	7	0	0	0
2. Specific Operational Requirements.	8	8	0	0	0
3. Development Concept Papers.	3	9	3	0	0
4. Proposed Technical Approaches.	0	9	6	0	0
5. Mission Element Need Statements.	3	8	4	0	0
6. Specific Behavioral Objectives.	2	5	4	5	0
7. entries in a task analysis.	0	5	2	6	3
8. entries in a functional flow block diagram.	0	7	3	2	3
9. entries in an operational sequence diagram.	0	7	2	3	3

- CONTINUE WITH TABLE B4 -

Table B4 (Continued)

Likely sources of information needed to write functional requirements include:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
10. outcomes of a function allocation procedure.	0	4	2	3	6
11. outcomes of a methods and media analysis.	0	1	7	1	6
12. operator/maintainer roles.	1	4	4	4	3
13. operator/maintainer duties.	2	3	3	4	4
14. operator/maintainer tasks.	2	3	2	4	5
15. statements of Navy needs.	4	9	2	1	0
16. interviews with non-human factors engineers directly involved in the system development process.	3	12	1	0	0
17. experience gained by direct, daily involvement of the writer(s) with non-HF engineers on the development team.	2	11	1	1	1
18. almost any source of information since it is impossible to anticipate where the proper information can be obtained.	4	6	0	2	4

- END OF TABLE B4 -

Table B5

Human factors support functions that require adequate functional requirements include:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. crew station design.	11	3	0	1	0
2. panel design.	12	2	0	1	0
3. control design.	12	2	0	1	0
4. display design.	12	3	0	0	0
5. function allocation procedures.	13	2	0	0	0
6. operator role definition.	12	2	1	0	0
7. maintainer role definition.	10	3	1	1	0
8. habitability and safety analysis.	4	7	2	2	0
9. functional flow block diagramming.	9	6	0	0	0

- CONTINUE WITH TABLE B5 -

Table B5 (Continued)

Human Factors support functions that require adequate functional requirements include:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
10. operational sequence diagramming.	7	8	0	0	0
11. anthropometric analyses.	3	1	6	5	0
12. selection of equipment components.	7	8	0	0	0
13. construction of time-line analyses.	5	10	0	0	0
14. crew size determinations.	10	5	0	0	0
15. task analyses.	9	6	0	0	0
16. operational trainer design.	8	4	2	1	0
17. maintenance trainer design.	7	5	2	1	0
18. accident analyses.	3	1	8	3	0

- CONTINUE WITH TABLE B5 -

Table B5 (Continued)

Human factors support functions that require adequate functional requirements include:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
19. system test and evaluation.	9	5	0	1	0

- END OF TABLE B5 -

Table B6

Functional requirements should be written without reference to:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. equipment. Thus, "Destroy enemy forces" is a better FR than "Destroy enemy submarines."	0	0	1	7	8
2. equipment specified to implement an intended function. Thus, "Destroy enemy submarines" is a better FR than "Destroy enemy submarines with torpedoes."	3	5	2	3	3
3. specific, currently available equipment. Thus, "Destroy enemy submarines with torpedoes" is a better FR than "Destroy enemy submarines with the MK 46 torpedo."	3	5	2	4	2
4. outcomes of an implied function allocation process. Thus, "Accomplish MK 46 torpedo launch" is a better FR than "Pilot accomplish MK 46 torpedo launch."	5	9	2	0	0
5. specific human responses. Thus, "Pilot launch MK 46 torpedo" is a better FR than "Pilot press LAUNCH button on a torpedo control panel."	5	9	1	1	0
6. specific human responses with specific interface equipment. Thus, "Pilot press LAUNCH button on a torpedo control panel" is a better FR than "Pilot press LAUNCH button on MK 46 Torpedo Control Panel."	5	7	3	0	1

- END OF TABLE B6 -

Table B7

PLEASE NOTE: In items 1 through 7 inclusive, your opinion is expressed in the appropriate box as before for the part of the item preceding the two dashes. For example, in item 1. you check your opinion about the "size" (usually measured in terms of dollar cost) of the system--...." You can, if you want to, provide some bonus information by circling or underlining one of two words within brackets. The word you select as appropriate in the part of the item after the dashes should not, of course, influence your opinion about the item.

The probability that adequate functional requirements can be written depends, in part, on the:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. size (usually measured in terms of dollar cost) of the system--the (larger; smaller) the system, the higher the probability adequate FRs can be written.	2	7	3	3	1
2. number of people intended to operate/maintain the system--the (more; fewer) people needed, the higher the probability adequate FRs can be written.	2	5	4	4	1
3. point in the development process when FRs are written--the (earlier; later) in the process, the higher the probability adequate FRs can be written.	7	8	1	0	0
4. number of people involved in writing FRs--the (more; fewer) people involved, the higher the probability adequate FRs will be written.	2	6	4	3	0
5. number of people assigned to the system development team--the (more; fewer) people assigned, the higher the probability adequate FRs will be written.	1	6	6	2	0
6. complexity (use your own interpretation of complexity) of the system--the (more; less) complexity, the higher the probability adequate FRs will be written.	3	8	4	1	0

- CONTINUE WITH TABLE B7 -

Table B7 (Continued)

The probability that adequate functional requirements can be written depends, in part, on the:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
7. criticality (use your own interpretation of criticality) of the human role in the system--the (more; less) critical the role, the higher the probability adequate FRs will be written.	2	6	4	3	1

\- END OF TABLE B7 -

Note--Results of responses to clauses after the two dashes were:

Question#

1 no response=6; smaller=9; larger=1

2 no response=8; fewer=8

3 no response=1; earlier=13; later=2

4 no response=8; fewer=5; more=3

5 no response=8; fewer=4; more=4

6 no response=5; less=10; more=1

7 no response=7; less=4; more=5

Due to the large number of no response cases, results were disregarded.

Table B8

A document of instructions for writing functional requirements:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. could be written.	4	11	1	0	0
2. does not exist presently.	4	7	4	0	1
3. if well written and understandable to individuals involved in system development, would be useful.	8	8	0	0	0
4. is not worth the effort required to produce it.	0	0	3	9	4
5. is not needed since the procedure for writing functional requirements is an art similar to writing musical masterpieces and thus cannot be described.	0	0	0	12	4
6. is not needed since the procedure for writing functional requirements is well known.	0	0	2	8	6
7. is a waste of time since even a good document would not be used by individuals on the system development team.	1	0	4	9	2
8. is impossible to write since it is unlikely two people of equivalent backgrounds, using the document, would produce essentially identical functional requirements.	0	0	4	9	3
9. is impossible to write since the procedure varies too much from one system to another.	0	0	0	12	3

- CONTINUE WITH TABLE B8 -

Table B8 (Continued)

A document of instructions for writing functional requirements:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
10. would be a set of step-by-step procedures.	1	8	4	3	0
11. would describe a very complex process and require special skill, experience and training to follow.	0	6	1	7	2
12. would be little different from a text devoted to discussions of thinking and writing clearly.	0	3	2	9	2
13. would not provide instructions for a procedure or process to follow; rather, the document would provide general guidelines for writing functional requirements.	1	4	2	8	1

- END OF TABLE B8 -

Table B9

A document of instructions for writing functional requirements, if one is written, should include a section:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. clearly defining functional requirements and the general issues involved in writing good ones.	12	4	0	0	0
2. on the need for clarity in thinking and writing along with suggestions and references for achieving clarity.	4	9	3	0	0
3. of a generous number of examples of adequate, marginal and inadequate FRs along with explanations why each of the examples was classified as it was.	10	6	0	0	0
4. describing the various uses HF engineers have for functional requirements.	4	10	1	1	0
5. describing the kinds and sources of information required to write adequate functional requirements.	10	6	0	0	0
6. describing the kinds of problems typically encountered in writing functional requirements along with suggestions for overcoming the problems.	9	6	1	0	0
7. providing an example of how an existing system evolved and where in the evolution functional requirements would have been needed, what the functional requirements should have looked like and how they would have been used by human factors engineers.	8	7	1	0	0

- END OF TABLE B9 -

Table B10

Version presented to HFEs
Most non-human factors engineers believe human factors engineers:

Version presented to nHFEs
Human Factors Engineers (or Engineering Psychologists):

Statement	Group	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. should have formal training as engineers and then get some additional training in psychology.	HFEs	1	8	2	4	1
	nHFEs	1	14	2	13	3
2. don't provide anything more than common-sense suggestions to the system development process.		4	7	2	2	1
		0	3	1	19	9
3. provide services that cost too much money to be worthwhile in the development process.		5	8	0	3	0
		0	1	2	18	12
4. provide services that are too time-consuming to be worthwhile in the development process.		4	7	3	2	0
		0	2	4	15	12
5. can't respond to system development problems without first proposing a lengthy "investigation."		2	12	0	2	0
		2	12	4	12	3
6. have little or nothing of value to contribute to the system development process.		0	6	5	3	2
		0	1	0	10	22
7. promise a great deal but deliver very little.		2	10	2	1	1
		0	7	6	10	10
8. use a lot of jargon that even other human factors engineers do not really understand.		0	6	6	2	2
		0	3	4	11	13

- CONTINUE WITH TABLE B10 -

Table B10 (Continued)

Version presented to HFEs: Most non-human factors engineers believe human factors engineers: / Version presented to nHFEs: Human Factors Engineers (or Engineering Psychologists):		I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
9. have a useful role in the system development process.	HFEs	0	6	2	7	1
	nHFEs	18	14	0	0	1
10. want a role in system development, but when they are given a role they don't know what to do next.		1	9	1	4	1
		1	5	8	12	7
11. are insensitive to demands and responsibilities non-human factors engineers face in system development.		0	11	2	3	0
		1	9	6	9	6
12. are unaware of the factors that really determine events and decisions in the system development process.		3	5	3	5	0
		1	9	3	13	7
13. are arrogant.		0	1	6	6	3
		0	2	2	13	14
14. are not good "team players."		0	6	3	6	1
		0	4	4	12	12
15. work in system development only against their will.		0	1	3	10	2
		0	1	9	15	7
16. work in system development because: a) the pay is good, b) the work is easy and c) accountability for their performance does not exist.		0	1	6	7	2
		0	0	8	14	9

- CONTINUE WITH TABLE B10 -

Table B10 (Continued)

Version presented to HFEs
Most non-human factors engineers believe human factors engineers:

Version presented to nHFEs
Human Factors Engineers (or Engineering Psychologists):

		I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
17. would rather do research in human behavior than work in system development.	HFEs	0	2	9	4	1
	nHFEs	2	8	12	7	1
18. are useful only to suggest arrangements for the location of controls and displays at the man-machine interface.		3	8	3	1	1
		1	3	2	21	6
19. are welcomed in the system development process.		0	2	2	11	1
		2	16	5	7	2
20. try to "horn in" on a process where they are not wanted.		0	11	1	4	0
		0	1	3	22	5
21. are unwilling to "work in the trenches" with working level non-human factors engineers.		1	7	4	3	1
		0	5	4	13	9
22. should not have responsibility for deciding if a human or a machine should accomplish a given system function.		0	10	3	2	1
		2	7	2	14	6
23. overemphasize the role of the human in the system.		1	10	1	4	0
		1	3	1	21	6
24. should be involved in the system development process but only after major equipment components have been selected.		3	10	0	2	1
		1	1	0	19	12

- CONTINUE WITH TABLE B10 -

Table B10 (Continued)

Version presented to HFEs
Most non-human factors engineers believe human factors engineers:

Version presented to nHFEs
Human Factors Engineers (or Engineering Psychologists):

		I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
25. are not satisfied with the non-human factors engineers' selection of interface components.	HFEs	0	11	4	1	0
	nHFEs	2	11	11	6	1
26. are least welcome at the concept formulation state of the development process.		1	7	4	3	1
		4	8	5	12	4
27. may be O.K., but the ones I have actually worked with did not live up to expectations.		0	10	3	3	0
		0	6	4	9	12
28. would rather work with other human factors engineers than with non-human factors engineers.		0	6	6	3	1
		1	9	11	6	1
29. are useful only in support services, (e.g., training system design, test and evaluation) after prototype models of the system have been built.		2	8	4	2	0
		0	0	1	16	16
30. should be restricted to designing comfortable and attractive crew stations.		2	5	7	2	0
		0	0	2	13	18
31. do not appreciate the speed with which things happen during the system development process.		3	11	1	1	0
		3	11	5	9	5
32. should not have final authority in any decision in the development process.		5	9	2	0	0
		4	9	4	11	3

- CONTINUE WITH TABLE B10 -

Table B10 (Continued)

Version presented to HFEs
Most non-human factors engineers believe human factors engineers:

Version presented to nHFEs
Human Factors Engineers (or Engineering Psychologists):

		I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
33. treat each system problem they are asked to help resolve as if it were the first time the problem had ever come up.	HFEs	1	10	3	2	0
	nHFEs	1	9	3	18	2
34. are responsible for any inadequacies in communication or cooperation between non-human factors and human factors engineers.		0	3	10	2	1
		0	0	5	13	14

\- END OF TABLE B10 -

Table B11

Most human factors engineers believe non-human factors engineers:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
1. are unable to think in abstract terms.	2	5	4	4	1
2. are incapable of thinking in new and novel terms.	1	8	1	5	1
3. talk in jargon even other non-HF engineers don't understand.	0	6	6	4	0
4. have probably chosen to become engineers because they are uncomfortable with the unpredictability they believe is the characteristic of human behavior.	1	4	6	3	2
5. are arrogant.	0	4	3	8	1
6. are unconvinced about the usefulness of an HF discipline.	2	14	0	0	0
7. are convinced the HF discipline has some, but vague, role in the system development process.	0	13	2	1	0
8. are willing to give only "lip service" to the need for HF involvement in the system development process.	2	14	0	0	0
9. are afraid HF engineers will interfere with the non-HF engineer's prerogative to make system design decisions.	1	12	3	0	0

- CONTINUE WITH TABLE B11 -

Table B11 (Continued)

Most human factors engineers believe non-human factors engineers:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
10. do not appreciate the complexity, time and effort involved in human factors support services.	6	9	1	0	0
11. are unaware of the reasons for the lack of generality in the human factors data base.	4	8	4	0	0
12. when all is said and done, must have the principal authority to decide on the system that will be delivered to the fleet.	0	11	2	2	1
13. are biased to think in terms of equipment solutions to system functions.	8	7	1	0	0
14. want to develop new systems by improving the old ones.	0	13	2	1	0
15. do not know how and why HF engineers do what they do.	2	12	2	0	0
16. would not change their beliefs even if they were shown their beliefs are based on misinterpretation of fact.	0	5	3	7	1
17. cannot think of ways to accomplish system functions unless they start their thinking with some piece or type of equipment in mind.	3	9	1	3	0
18. are less intelligent than HF engineers.	2	1	4	6	3

- CONTINUE WITH TABLE B11 -

Table B11 (Continued)

Most human factors engineers believe non-human factors engineers:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
19. have had less training and practice at verbalizing their ideas than human factors engineers.	1	9	3	3	0
20. should be reduced to a very low level in the decision-making process in system development.	0	0	3	10	3
21. are quick to cut funds for human factors support services from the budget when funding is cut.	6	9	1	0	0
22. assign as many functions as possible to equipment and assign to humans only what unavoidably remains.	4	9	1	2	0
23. assume humans will adapt to the demands of the man-machine interface since humans have always done so in the past.	4	12	0	0	0
24. assume training will take care of helping humans adapt to any demands the system might impose.	4	12	0	0	0
25. look forward to the day when all system functions can be accomplished by machines and human factors problems will not exist.	0	7	6	2	1
26. rely on the difficulty of judging adequacy of human performance to escape accountability for equipment design decisions.	1	8	5	2	0
27. should, if they are going to interact with HF engineers, have at least some basic training in psychology.	0	4	5	7	0

- CONTINUE WITH TABLE B11 -

Table B11 (Continued)

Most human factors engineers believe non-human factors engineers:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
28. "hold all the trump cards" since non-human factors engineers make all final decisions in the development process.	2	10	4	0	0
29. are not good "team players."	0	1	5	10	0
30. do not feel any responsibility for the adequacy of human performance in the developed system when it is delivered to fleet.	1	14	0	1	0
31. are not satisfied with human factors engineering solutions for system design problems.	1	9	4	2	0
32. will abandon even an excellent HF engineering suggestion if the suggestion interferes with a constraint imposed by the needs of the equipment.	3	13	0	0	0
33. have no intentions of letting human factors engineers determine the form of the man-machine interface.	0	8	2	6	0
34. would prefer to work with other non-human factors engineers rather than with human factors engineers.	2	10	3	1	0
35. are responsible for any inadequacies in communication or cooperation between non-HF and HF engineers.	0	6	6	3	1

- CONTINUE WITH TABLE B11 -

Table B11 (Continued)

Most human factors engineers believe non-human factors engineers:	I AGREE COMPLETELY.	I TEND TO AGREE.	I'M UNCERTAIN IF I AGREE OR DISAGREE.	I TEND TO DISAGREE.	I DISAGREE COMPLETELY.
36. are jealous of their "turf" and don't want to lose any control.	1	11	2	2	0
37. are unaware that they are not doing what the human factors engineers think they should be doing when non-HF and HF engineers cooperate in system development.	0	7	7	2	0
38. when they become managers of system development, remain biased against human factors engineering.	1	10	0	5	0
39. are convinced HF engineering is too young a discipline to be useful in solving today's system development problems.	0	4	6	5	1

- END OF TABLE B11 -

Appendix C

Sixteen HFEs and 33 nHFEs responded to questionnaire items. For each item, respondents selected one from among five categories, viz.:

C_1 = I AGREE COMPLETELY

C_2 = I TEND TO AGREE

C_3 = I'M UNCERTAIN IF I AGREE OR DISAGREE

C_4 = I TEND TO DISAGREE

C_5 = I DISAGREE COMPLETELY

The number of responses in a distribution (N) was not always 16 or 33 since respondents could ignore any item by not responding to the item. Observed N values in this exercise were 15 or 16 for HFEs and 28, 30, 31 or 33 for nHFEs.

Response distributions for each item represent opinions of the group about corresponding items. The distribution Median represents one statistical summary of group opinion. To compute distribution Medians, class limits for categories were set at:

$$C_1 = .500 \text{ to } 1.499$$

$$C_2 = 1.500 \text{ to } 2.499$$

$$C_3 = 2.500 \text{ to } 3.499$$

$$C_4 = 3.500 \text{ to } 4.499$$

$$C_5 = 4.500 \text{ to } 5.499$$

With the limits set above, the following is true:

$$1.000 \leqq \text{Median} \leqq 5.000$$

When all cases are observed in C_1, the Median is 1.000. C_1 represents complete agreement with the associated item. Thus, when the Median is 1.00, all respondents indicate complete agreement with the associated item. Likewise, when the Median = 5.00, all respondents indicate complete disagreement with the item. Thus, distribution Medians represent points on an ordinal scale from complete agreement (Mdn. = 1.00) to complete disagreement (Mdn. = 5.00).

To determine whether or not a distribution represents consensus of opinion, observed distributions were compared to distributions expected by chance. For N values encountered in this exercise the probability of occurrence, by chance, of various sums of frequencies in C_1 and C_2 or C_4 and C_5 was determined. For example, when 16 things are distributed to five categories, 4,845 different distributions can be formed.[1] For 17 of the 4,845 distributions $C_1+C_2 = 16$,

[1] A computer program for listing properties of distributions of N values in this exercise is available from the author.

viz.: $C_1 = 16$, $C_2 = 0$; $C_1 = 0$, $C_2 = 16$; $C_1 = 15$, $C_2 = 1$; $C_1 = 1$, $C_2 = 15$; ... $C_1 = 9$, $C_2 = 7$; $C_1 = 7$, $C_2 = 9$; $C_1 = 8$, $C_2 = 8$. Likewise, for 17 distributions $C_4+C_5 = 16$. Thus, for 34 of 4,845 distributions C_1+C_2 or $C_4+C_5 = 16$. Consequently, the probability of randomly drawing a distribution from among the 4,845 possible, where C_1+C_2 or $C_4+C_5 = 16$ is given by 34/4,845 or .007. In the same manner, it can be shown C_1+C_2 or $C_4+C_5 = 15$ in 96 of the 4,845 distributions. Thus, the probability of randomly drawing a distribution where C_1+C_2 or $C_4+C_5 = 15$ is 96/4,845 or .02. Consequently, the probability of randomly drawing a distribution wherein C_1+C_2 or $C_4+C_5 = 15$ or more is given by .007+.020 or .027. Table C1 shows probability values for randomly-drawn distributions wherein C_1+C_2 or C_4+C_5 equal or exceed tabled values for N values encountered in this exercise.

Table C1 shows criterion values, to apply to observed distributions, for each N value. For example, when N=15, the criterion value is 13. Thus, an observed distribution where N=15 and C_1+C_2 or $C_4+ C_5$ equals or exceeds 13, is taken to represent consensus of opinion for the group with the associated item. Criterion values for N=16, 28, 30, 31, 32 and 33 were 13, 24, 26, 26, 28 and 28 respectively (See Table C1). If the criterion value is met or exceeded in C_1 and C_2, consensus of opinion is for agreement. If the criterion value is met or exceeded in C_4 and C_5, consensus of opinion is for disagreement. Distributions wherein criterion values are not met represent no consensus of opinion or uncertainty.

Table C1

Probability C_1+C_2 or C_4+C_5 = S in a Randomly-Drawn Distribution with Five Categories

(Selected Values for N)

S	N: 15	16	28	30	31	32	33
13	.074	.122					
14	.031	.064					
15	.008	.027					
16		.007					
24			.104				
25			.053				
26			.023	.086	.140		
27			.008	.044	.080		
28			.002	.019	.041	.081	.118
29				.006	.018	.041	.067
30				.001	.006	.018	.034
31					.001	.006	.015
32						.001	.005
33							.001

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